Availability of Ground Water in York County, Nebraska

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1839-F

Prepared in cooperation with the State of Nebraska Conservation and Survey Division, University of Nebraska

Availability of Ground Water in York County, Nebraska

By C. F. KEECH, V. H. DREESZEN, *and* P. A. EMERY

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1839-F

Prepared in cooperation with the State of Nebraska Conservation and Survey Division, University of Nebraska

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1967

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

TABLE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

AVAILABILITY OF GROUND WATER IN YORK COUNTY, NEBRASKA

By C. F. KEECH, V. H. DREESZEN, and P. A. EMERY

ABSTRACT

York County, an area of 575 square miles, is situated on an upland plain in southeast Nebraska. Although tributaries of the Big Blue River have eroded valleys into this plain, much of the original surface is still intact and is characterized by broad shallow undrained depressions. The economy is based almost wholly on agriculture, and corn is the major crop. More than 111,000 acres of cropland was irrigated in 1964 with water pumped from 1,240 wells.

The upland plain is underlain to depths of 100–450 feet by unconsolidated deposits of Quaternary age. The upper part of this depositional sequence consists largely of wind-deposited clayey silt, and the lower part consists of stream-deposited sand and gravel. In part of the county, the sequence includes some glacial till also. The unconsolidated Quaternary deposits mantle the eroded surface of marine strata of Cretaceous age.

The lower unconsolidated rocks of Quaternary age are saturated and constitute a highly productive aquifer throughout much of the county. Replenishment to this aquifer, derived principally from precipitation, is believed to average about 1.5 inches per year. As the quantity of ground water pumped per year greatly exceeds the average annual quantity of recharge, most of the water used for irrigation is from storage. Consequently, water levels have been trending downward. A comparison of 1964 water levels in wells with water levels measured in 1953 shows that the water table declined more than 10 feet beneath 42 square miles.

The ground water is of the calcium bicarbonate type, and, though hard, is chemically suitable for irrigation use on most soils in the county.

INTRODUCTION

York County is a nearly square area of 575 square miles (368,000 acres) in southeastern Nebraska (fig. 1). York, the county seat, is at the center of the county and is 50 miles west of Lincoln, the State capital. The principal streams in the county are the West Fork of the Big Blue River, Beaver Creek, and Lincoln Creek.

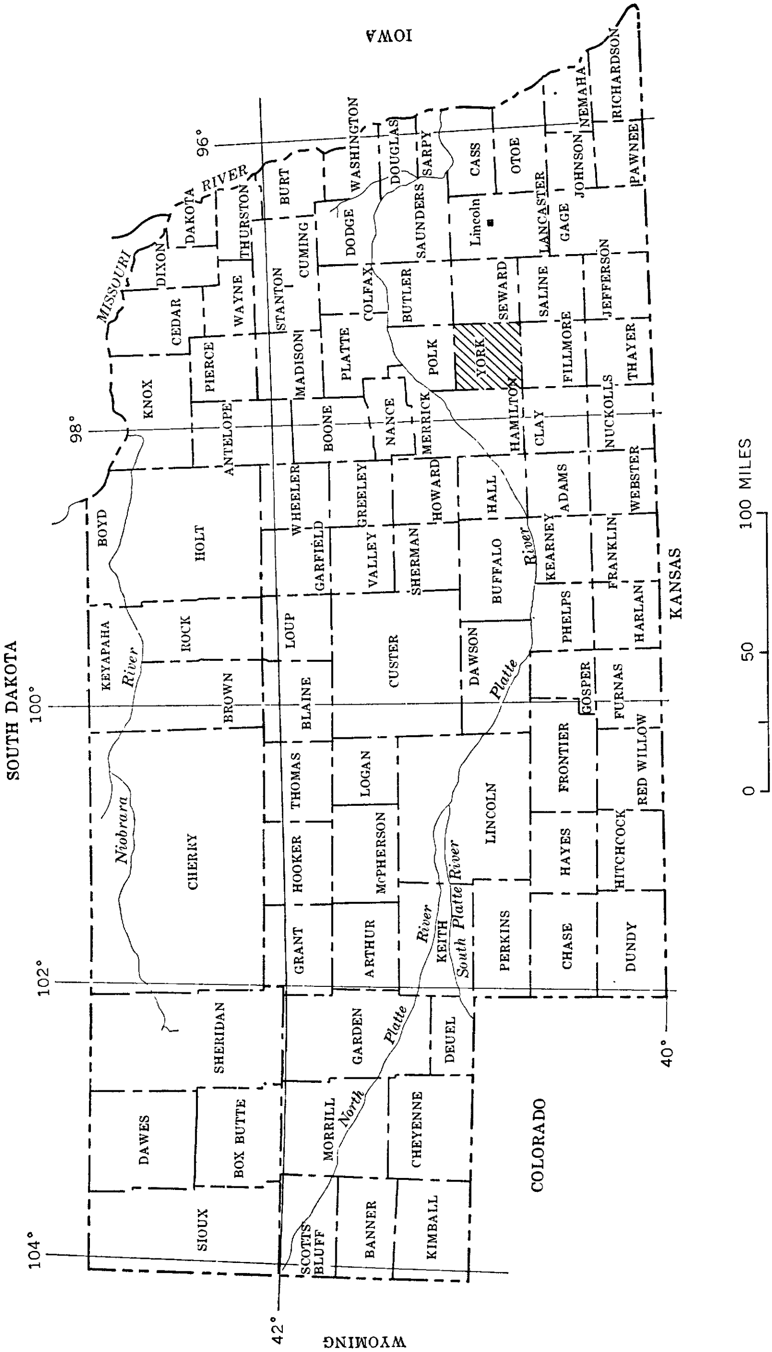

FIGURE 1.—Location of York County.

About 85 percent of York County is nearly level to strongly rolling upland. Most of the upland, however, is gently undulating and is characterized by numerous shallow, basinlike depressions generally ranging in size from 1 to several hundred acres. The most strongly rolling upland is the result of valley-side erosion along the principal drainages. The remaining 15 percent of York County consists of valley terraces and flood plains. Beaver and Lincoln Creeks have cut valleys to an average depth of about 40 feet below the upland, and the West Fork of the Big Blue River has cut to depths ranging from 60 to 100 feet.

Before the late 1940's ground water in York County was used principally for domestic, stock, and municipal supplies, and demands for large amounts were not numerous. Only 140 irrigation wells were in operation in 1949, and most of these had been drilled in 1947–48. Success of well irrigation demonstrated to dryland farmers that irrigation could spell the difference between crop failure or success; thus when fields became parched by drought in the middle 1950's, irrigation wells were drilled as rapidly as possible.

After the drought ended in the spring of 1957, drillers were able to catch up with backorders for wells. By the end of the summer of 1957, there were more than 1,000 irrigation wells in York County (fig. 2), and the rate of withdrawal of ground water was 10 times greater than it had been a decade earlier. Some residents began to express concern as to whether the ground-water supply would be adequate for continued withdrawals at this rate.

This report is an appraisal of the present (1964) ground-water supply and its availability. The study was made cooperatively by the U.S. Geological Survey and the Conservation and Survey Division of the University of Nebraska. A series of unpublished maps and geologic sections depicting the geology and hydrology of York County was prepared as part of the cooperative study by E. C. Reed, director of the Conservation and Survey Division, University of Nebraska. Pertinent information from those illustrations is incorporated in this report. A basic-data report for York County (Keech, 1964) contains tabulated data on water quality and inventoried wells.

CLIMATE

The climate of York County is subhumid. The annual precipitation generally ranges from 15 to 40 inches; the average is about 27 inches. The most precipitation generally falls during the growing season—May, June, and July—the least falls in November, December, and January. Spring and summer rains usually occur as local thundershowers, whereas fall and winter precipitation normally results from widespread storms. Droughts are rather common, particularly in late summer, and they reduce the yield of nonirrigated crops. However, total crop failures are rare.

The mean annual temperature is 51.5°F. January temperatures often drop below zero, and July temperatures occasionally are higher than 100°F.

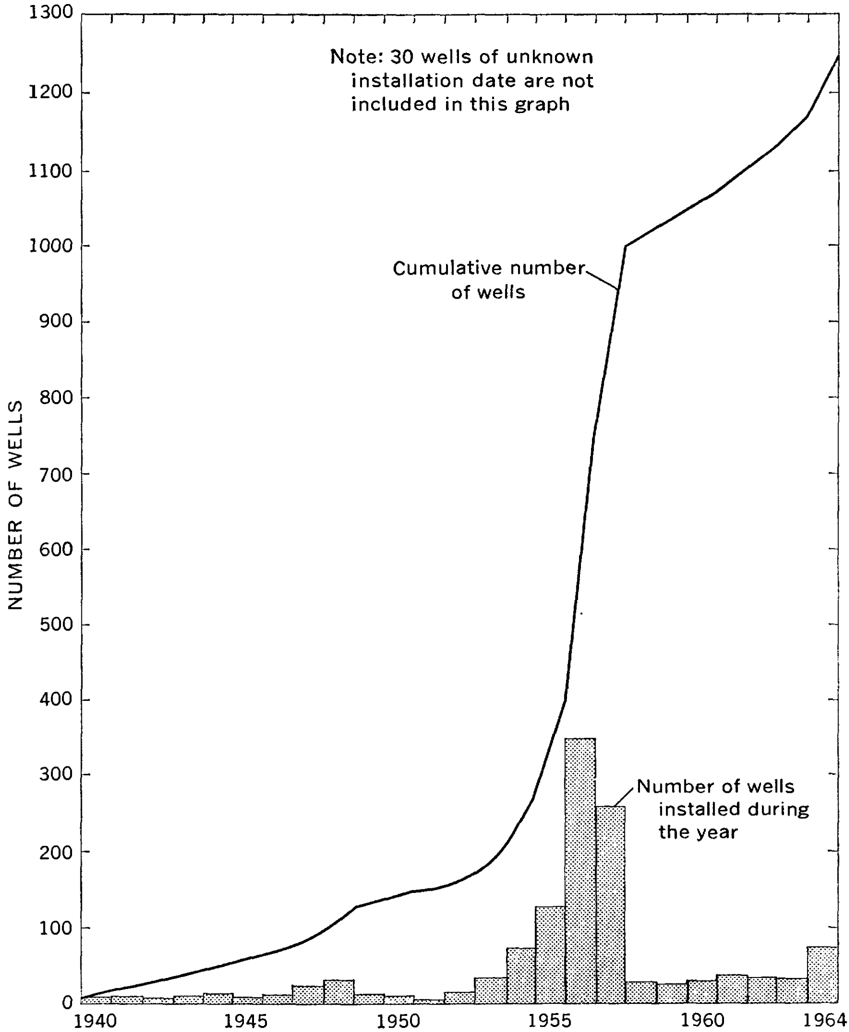

Figure 2.—Rate of installation of irrigation wells.

The prevailing wind is from the northwest in fall and winter and from the south in spring and summer. Strong winds are common, especially in spring. Tornadoes are reportedly rare, although several occurred during the spring of 1964. On May 5, 1964, a particularly severe tornado crossed the county from southwest to northeast, passing along the west side of both Bradshaw and Benedict. It killed two people and damaged or destroyed many farm buildings and homes.

AGRICULTURE AND SOILS

Agriculture dominates the economy of York County. About 90 percent of the land is arable, and most of this is also irrigable. As ground water is available beneath most of the county, each year more land is irrigated with well water.

Corn has been the major crop in the county almost from the time that the native prairie was turned by the plow. Corn yields have been increased considerably by irrigation, and crop failures resulting from drought have been eliminated in irrigated areas. In 1964, according to Nordquist and Logan (1965), the corn grown for grain occupied a total of 75,410 irrigated acres and 18,850 nonirrigated acres. Irrigated corn yielded an average of 77.7 bushels per acre whereas nonirrigated corn yielded only 27 bushels. Other important crops were winter wheat, planted on 50,100 acres; grain sorghum, 55,620 acres, of which 16,690 was irrigated; and alfalfa hay, 13,230 acres. An estimated 1,240 wells irrigated about 111,400 acres at the end of the 1964 growing season.

Hayes and Goke (1928), who described the soils of York County, found that all the soils except those on severely eroded slopes or in small areas of recently deposited sand have dark-colored, almost black topsoils that differ considerably in thickness. The subsoils range from loose sand to dense, nearly impervious clay. These differences greatly affect the storage of available moisture in the topsoil and influence the crop yields. They also influence the rate of water infiltration to the ground-water reservoir. Sandy subsoils permit a considerable amount of the precipitation to filter to the water table, whereas heavy clay subsoils tend to retard water movement. The rate of infiltration is slowest on the steeper slopes, where water quickly runs off to the streams, and in the depressions, where most of the water that collects is evaporated. Subsoils in undrained depressions, locally called claypan, are nearly impervious to depths of 5 or 6 feet.

As the natural texture and structure of the soil have been destroyed by tilling, the ability of the soil to absorb and transmit water down-

268-823—67——2

ward probably is not the same as it was when the prairie sod was still intact. Land leveling, terracing, irrigation, and construction of artificial drains also have affected the rate of recharge to the ground-water reservoir, and more intense use of the land will result in further changes.

GEOLOGY

ROCKS AND THEIR WATER-YIELDING PROPERTIES

The size, shape, and arrangement of the openings in rocks determine how much water the rocks can store and transmit. If rock contains a great many connected pore spaces of sufficient size, water can move freely through it and the rock is said to be highly permeable. Wells in highly permeable saturated rock will yield large amounts of water, but wells in saturated rock whose openings are small or poorly connected will yield only small amounts of water. Plate 1 shows the potential yield of rocks of Quaternary age in York County.

The storage capacity of rocks may be likened to that of reservoirs, and the ability of rocks to transmit water may be likened to that of filters. Thus, the rocks both store and transmit water, and to investigate the availability of ground water it is necessary to study the rocks that contain the ground water.

A deep test hole drilled at any place in York County would first penetrate unconsolidated rock; then, consolidated sedimentary rock; and finally, at approximately 3,000 feet below the surface, igneous and metamorphic rocks, known as basement rock.

The unconsolidated rock consists of clay, silt, sand, gravel, and till, all of Quaternary age and referred to collectively as mantle rock. The consolidated rock is commonly referred to as bedrock. In York County, the bedrock immediately underlying the mantle rock is composed of formations of Cretaceous age. (See pl. 2.) Table 1 is a generalized section indicating the order, physical character, and water-bearing properties of the geologic formations in York County.

In York County, the driller generally considers that the surface of the bedrock is the lowest limit from which potable water can be obtained. Although some bedrock formations are water bearing, the water generally is too saline to be potable. In a few places, however, the upper part of the bedrock may be fractured or creviced and may yield large quantities of potable water.

TABLE 1.—*Generalized section of the geologic formations and their water-bearing properties, York County, Nebr.*

System	Series	Stratigraphic unit	Thickness (feet)	Character and distribution	Water supply
Quaternary	Recent	Surficial alluvium, loess and soil	0–5±	Widespread soils; flood-plain deposits of clay, silt, sand, and gravel; isolated windblown deposits of silt and clay.	Significant only in that it transmits water to recharge the ground-water reservoir.
	Pleistocene	Unconsolidated deposits	110–450	Wind deposits of clay and silt underlain by relatively thick stratified stream deposits of sand and gravelly sand interbedded with wind- and water-laid deposits of clay and silt and some ice-deposited nonsorted and nonstratified glacial till; underlie entire county.	The principal source of water to wells in the county. Yields abundant supplies about in proportion to the saturated thickness of the sand and gravel deposits. Those deposits above the water table are significant principally as a transmitting medium in recharge of the ground-water reservoir.
Cretaceous	Upper Cretaceous	Niobrara Formation	0–100	Yellow and light- to dark-gray marine chalky shale and chalk; underlies much of the county.	Not a source of water supply to wells.
		Carlile Shale	0–350	Medium- to dark-gray marine shale, calcareous in the lower part; underlies much of the county.	Do.
		Greenhorn Limestone	0–30	Gray fossiliferous limestone interbedded with calcareous shale; underlies much of the county.	Do.
		Graneros Shale	0–65	Dark-gray shale, calcareous in the upper part; underlies most of the county.	Do.
	Lower Cretaceous	Dakota Sandstone	300–675	Interbedded clay shale, sandy shale, and sandstone; underlies entire county.	Contains mineralized water; wells in York County are not sufficiently deep to reach this formation.

Only one test hole in the county has been drilled to the basement rock. This was an exploratory oil-test hole drilled in sec. 11, T. 12 N., R. 2 W. Mr. M. P. Carlson, subsurface geologist of the Conservation and Survey Division of the University of Nebraska, examined the rock cuttings and prepared the following summary of stratigraphic units that he identified.

Log of York Development Rohr 1, SW¼SW¼NW¼ sec. 11, T. 12 N., R. 2 W. Altitude of land surface, 1,849 feet

	Depth below land surface (feet)		
	From	*To*	
Quaternary System (clay, silt, sand, and gravel)	0	370	
Cretaceous System			
Carlile Shale	370	390	
Greenhorn Limestone and Graneros Shale	390	440	
Dakota Sandstone (sandstone and shale)	440	1,095	725'
Pennsylvanian System (limestone and shale)	1,095	1,995	900'
Mississippian System (dolomite and limestone)	1,995	2,060	65'
Devonian System (dolomite, sandy near base)	2,060	2,230	170'
Silurian System (cherty dolomite)	2,230	2,265	35'
Ordovician System (dolomite, sandstone, and shale)	2,265	2,877	612'
Cambrian System (dolomite and sandstone)	2,877	2,990	113'
Precambrian (granofels)	2,990	3,000	10'

The bedrock surface (pl. 1) is characterized by three major east-trending valleys separated by broad parallel ridges. A prominent broad bedrock hill capped by the Niobrara Formation underlies an area west of the city of York at a shallow depth. Ridges and valleys that were topographic features at the beginning of Quaternary time are now covered by a mantle of unconsolidated Quaternary rocks. Thus, the present topography does not resemble the configuration of the bedrock surface.

ROCKS OF CRETACEOUS AGE

DAKOTA SANDSTONE

The Dakota Sandstone, which consists of interbedded shale and sandstone, underlies all of York County and is the oldest bedrock unit that is in contact with the overlying unconsolidated Quaternary rocks. In the southeastern part of the county (SE¼SE¼ sec. 3, T. 9 N., R. 1 W.) the upper few feet of the Dakota was penetrated in a test hole; here the Dakota forms the floor of the deepest known part of a buried channel. The Dakota also forms the floor of the other two major buried channels, in the eastern part of the county. The depth to the upper surface of the Dakota increases from about 300 feet in the southeast corner of the county to about 700 feet in the northwest corner.

In general, less than half the total thickness of the Dakota Sandstone in the York County area is sandstone; the remainder is clay shale and sandy shale. The sandstone is fine to medium grained and is moderately to poorly cemented.

The quality of the water contained in the Dakota Sandstone in York County is unknown, but, judging from investigations made in other areas, the water probably is too mineralized for irrigation, domestic use, or even livestock use. Records of analyses of water from wells tapping the Dakota Sandstone in areas to the east and west of York County indicate that mineralization of the water in the Dakota increases westward and with greater depth.

GRANEROS SHALE

The Graneros Shale conformably overlies the Dakota Sandstone. It averages 60 feet in thickness and consists almost wholly of dark-gray shale. The lower half of the formation is noncalcareous, whereas the upper half is calcareous and contains thin layers of limestone. Because the shale is nearly impermeable, it will yield little water; no wells in the county are developed in it. The depth to the top of the Graneros increases westward and northwestward. The only test holes drilled into the Graneros are near the east border of the county.

GREENHORN LIMESTONE

Except where removed by post-Cretaceous erosion, the Greenhorn Limestone overlies the Graneros Shale. It is a sequence of interbedded gray fossiliferous limestone and calcareous shale and averages about 25 feet in thickness. Both the limestone and the shale of this formation are nearly impervious and are not potential aquifers except where fractured or creviced.

CARLILE SHALE

The Carlile Shale immediately overlies the Greenhorn Limestone. It is present in all but the eastern part of York County, where post-Cretaceous erosion removed it. Its thickness ranges from 0 to about 350 feet. The lower 70–90 feet of the Carlile consists of dark-gray calcareous shale interbedded with thin layers of fossiliferous limestone. The upper-part consists of medium- to dark-gray noncalcareous clay shale and locally contains a few feet of fine-grained sand near the top. The Carlile Shale is very fine textured and almost impervious.

NIOBRARA FORMATION

The Niobrara Formation conformably overlies the Carlile Shale. It is the youngest formation of Cretaceous age in York County and is present only in part of the western third of the county. The Niobrara consists of yellow and light- to dark-gray chalky shale and chalk. Owing to oxidation, the upper part of the Niobrara is yellow, white, orange, and yellow gray over the buried ridge and on the side slopes of the buried valley in southwestern York County. (See pl. 1.) The Niobrara ranges in thickness from 0 to 100 feet and is thickest in the northwest corner of the county.

The Niobrara Formation is not known to yield water to wells in York County, and it is not considered to be a potential water source except where it is fractured or creviced. Records on file at the Conservation and Survey Division, University of Nebraska, show that significant yields are obtained from the Niobrara at a few localities in the State. The upper few feet of the formation may contain crevices and solution channels that are saturated with water. These are more common in highly weathered shale, but are not everywhere present. The water in the Niobrara probably is more mineralized than is that in the overlying unconsolidated Quaternary rocks.

ROCKS OF QUATERNARY AGE

Glacial ice sheets advancing outward from centers of snow accumulation in Canada were either directly or indirectly responsible for the accumulation of the tremendous quantities of sand, gravel, silt, clay, and till that immediately underlie the land surface in York County.

When the first of the continental glaciers, the Nebraskan ice sheet, advanced southward into eastern Nebraska, it dammed the eastward-draining valleys and caused them to fill with impounded water and eventually to overflow. The overflow followed the ice margin southward. Meanwhile, the blocked valleys were being filled with sediment deposited by the streams. During the melting of the glacier and the retreat of the glacial margin, the older deposits were mantled by fine-grained wind- and stream-deposited materials. During the interglaciation that followed, the streams again entrenched and broadened their valleys, removing much of the material that had been deposited at the time of the Nebraskan Glaciation.

When the second continental glacier, the Kansan ice sheet, advanced, the valleys were again blocked by ice and again filled with coarse-grained sediments. It was during this glaciation that the till present in the mantle rock of York County was deposited. Again, during the waning phase of the Kansan Glaciation the coarse sediments and till were mantled by fine-grained material.

Neither of the two later glaciations (Illinoian and Wisconsin) reached York County. However, some sand and gravel was deposited as a result of glaciations in areas northeast of York County. River flats, kept free of vegetation by frequent floods, were subject to wind erosion, and great quantities of silt were blown into the uplands bordering the valleys to form the loess deposits that mantle much of York County. During the longer pauses in deposition, soils developed. Examples of fossil soils can be seen in some roadcuts in York County.

The unconsolidated deposits of sand and gravel constitute an immense permeable reservoir for ground-water storage, and it is these deposits that yield water to all the irrigation wells in York County. As the land surface, particularly in the upland areas, is more regular than the Cretaceous bedrock surface, the mantle of unconsolidated rocks tends to be thickest where it fills bedrock valleys and thinnest where it covers bedrock hills. In general, sand and gravel comprises a greater proportion of the thicker parts of the mantle of unconsolidated rocks and a smaller proportion of the thinner parts. Thus, wells drilled in areas underlain by bedrock valleys tend to have the greatest potential yield.

GROUND WATER

The ground water in the unconsolidated Quaternary rocks is derived from precipitation that falls as rain or snow in York County or westward from it. Part of the precipitation runs off the land surface to the streams, part evaporates, and the remainder infiltrates the soil. Generally, during the growing season, most of the precipitation that enters the soil is lost to the atmosphere by either evaporation or transpiration. However, during the nongrowing season, and at times during the growing season, some of the water that enters the soil infiltrates so deep that it is beyond interception by processes that would return it to the atmosphere. It is this water, then, that moves downward and becomes, eventually, recharge to the zone of saturation. The part of the precipitation that reaches the zone of saturation is estimated to be not more than 6 percent of the total, or about 1.5 inches during a year of normal rainfall. In drought years, lesser amounts of recharge may occur; and in wet years, more than 1.5 inches of water may be added to the zone of saturation. The fact that water reaches the zone of saturation is indicated by a rise of the water level in wells.

Plate 1 shows the depth to and the configuration of the water table, or upper surface of the zone of saturation, in York County. In general, the depth to water is greatest beneath the highest points of the divides between streams, and shallowest near the streams. Throughout most of the upland the depth to water ranges from 80 to 100 feet, becoming shallower near the stream valleys. The water table generally is less than 50 feet below the land surface in the valleys, and it may be less than 20 feet near the streams.

The configuration of the water table in York County is similar to that of the land surface except that it is smoother and has less relief. In places where the rate of recharge is exceptionally high, the water table may become mounded and then spread laterally outward. Depressions in the water table indicate localities where ground water is discharging, as along perennial streams and at pumped wells.

In general, the water table slopes eastward at an average gradient of about 7 feet per mile. Because ground water moves in the direction of the maximum slope of the water table, it percolates generally eastward through the water-bearing sediments. Except near wells that are being pumped, the water moves very slowly, probably less than 300 feet per year. All the water percolating into the county from the west is derived from recharge west of York County. To this is added the recharge within York County. Ground water that is not discharged naturally or pumped from wells moves on eastward to points of discharge outside the county. A pronounced trough in the water table along the valley of the West Fork of the Big Blue River is the result of ground-water discharge in the valley—either directly to the stream, to transpiring vegetation, or to the atmosphere by evaporation from the land surface.

Even though water-table (nonartesian) conditions exist throughout York County, there are areas where the water in the lower part of the Quaternary aquifer is under artesian pressure. This condition occurs in areas where saturated sand or gravelly sand is overlain by an extensive confining body of fine-textured material such as glacial till or clayey silt. The largest of these areas is the central part of the county.

Pumping from wells that tap these artesian zones results in high initial drawdown and widespread reduction in artesian head. With cessation of pumping, at the end of each irrigation season, water levels recover almost as rapidly as they declined.

These effects have caused considerable consternation to some farm operators, because the yields of wells drilled and test pumped during the nonirrigation season are significantly less during the irrigation season owing to the large and widespread decline of water levels that occurs when a great many wells are pumped.

Figure 3 shows hydrographs of two observation wells located within 6 feet of each other in NE¼NW¼ sec. 31, T. 11 N., R. 2 W. One of the wells is of sufficient depth and is so constructed as to monitor the artesian conditions, and the other reflects changes in the water table above a body of till. The rather large decline and recovery in artesian head are shown by the hydrograph of the deep well (No. 2). The hydrograph of the shallow well (No. 1) reflects the effects of pumping for irrigation from the unconfined aquifer.

STORAGE AND THE EFFECT OF PUMPING

When the rate of discharge from a ground-water reservoir equals the rate of recharge to it, the ground-water system is said to be in equilibrium. Changes in the ratio of discharge to recharge result in a change in the position of the water table. By periodically measuring the depth to water in wells, changes in ground-water storage can be determined. Plate 1 shows the net change in the water table for the period May 1953 to May 1964. Of 48 wells measured in both 1953 and 1964, 47 had lower water levels in 1964.

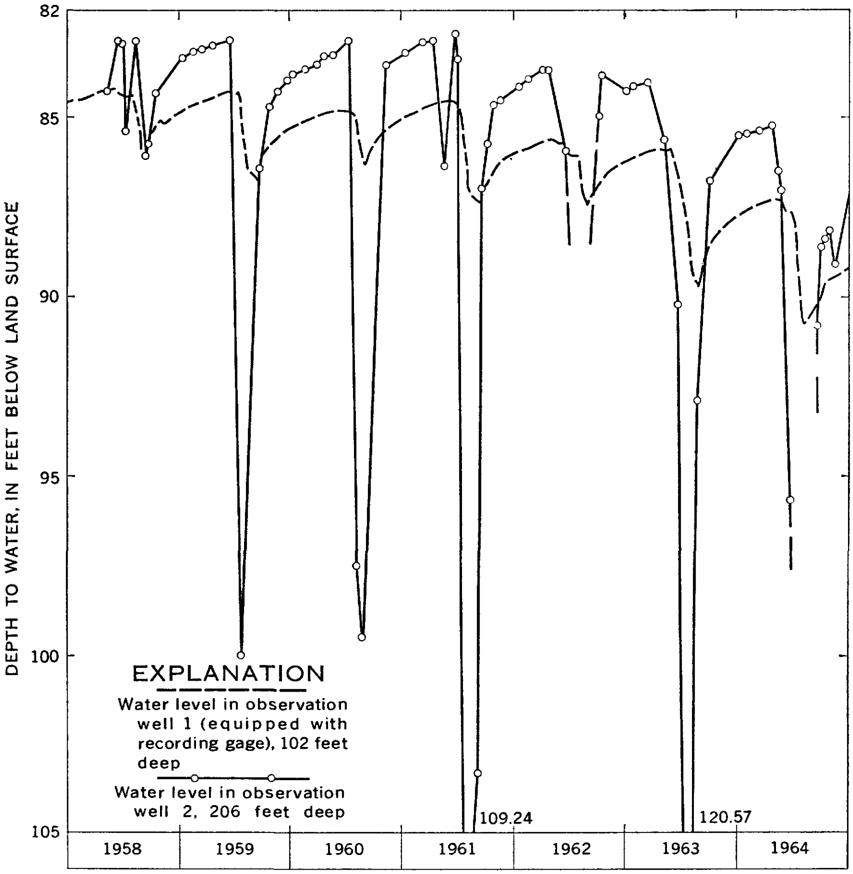

FIGURE 3.—Hydrographs of observation wells 1 and 2 in NE¼NW¼ sec. 31, T. 11 N., R. 2 W.

In 1964, water levels in wells were more than 4 feet lower in an area of about 282 square miles, or nearly half the county, and more than 10 feet lower in an area of 42 square miles. Even though the average amount of lowering is small, the evidence indicates that the rate of decline is as much as 1 foot per year in some areas.

Extensive consumptive use of ground water lowers the water table, reduces the quantity of water in storage, and decreases the rate of natural discharge. The degree to which these effects occur depends upon the quantity of water consumptively used, the distribution and concentration of the wells, the amount of recharge, and the distances and gradients to points of natural discharge.

The downward trend of water levels can be reduced only by decreasing the amount of water withdrawn or by significantly increasing the amount of water recharging the reservoir. Soil and water conservation practices that increase infiltration rates in the soil and reduce nonproductive evapotranspiration from soils and evaporation from water surfaces may increase ground-water recharge. These practices may also decrease the amount of water needed from supplemental sources. Control and storage of runoff waters might be used to supplement irrigation requirements and would provide additional recharge to the ground-water reservoir. Evaluations of the effective use of irrigation water should be made in relation to the crops irrigated, value returned, time of irrigation, and amount of water supplied. If it were possible to transport excess water into the area from an outside source, it would assist in reducing the rate of withdrawal of ground water from storage.

The amount of ground water stored in the saturated sand and gravel beneath York County is estimated to be about 10 million acre-feet—enough to form a lake covering the county to a depth of 27 feet. It should be emphasized, however, that the immense size of the reservoir is no indication of its ability to yield water on a continuing basis. Water has been accumulating in the reservoir for several centuries. Even though use of ground water for irrigation is relatively new, the amount of water already used probably represents an accumulation of many years.

For the most part, the ground-water supply of York County has been developed without consideration of the effect on the availability of future water supplies. If continued, this practice will lead to problems. So long as the supply is adequate and the climate is near normal, competition will be small; but as the supply diminishes, particularly during long periods of subnormal precipitation, competition will become keener. Thus, to obtain the most benefit from the water resources of the area, development should be accompanied by planning based on an adequate continuing appraisal of the supply.

CHEMICAL QUALITY

The chemical quality of water depends principally on the quantity and kinds of the dissolved constituents. Information on these constituents aids in classifying the water as to suitability for different uses and as to the geologic source.

A sample of ground water was obtained from each of 24 wells that are distributed fairly uniformly throughout York County in Pleistocene sand and gravel. The samples were analyzed by the U.S. Geological Survey according to standard methods described by Rainwater and Thatcher (1960). Results of the analyses (Keech, 1964) show that the water is low in dissolved solids, ranging in concentration from 250 to 428 ppm parts per million. The water is of the calcium bicarbonate type, and its chemical composition is nearly uniform.

Generally, the chemical quality of the water meets the drinking-water standards of the U.S. Public Health Service (1961). However, manganese in excess of the standard of 0.05 ppm was detected in 5 of the 24 samples. Manganese is not considered physiologically harmful, although it may cause an unpleasant taste or stain laundry. One sample, which was from a well in the NW¼ sec. 30, T. 11 N., R. 1 W., contained nitrate slightly in excess of the standard of 45 ppm.

For industrial and domestic uses, water containing high concentrations of calcium and magnesium, which cause hardness, can result in high soap consumption, scale formation in boilers, and other undesirable effects. One classification of hardness that is widely used is shown below (American Society for Testing Materials, 1960).

Range in hardness (ppm as $CaCO_3$)	*Descriptive classification*
<60	Soft
61–120	Moderately hard
121–180	Hard
>180	Very hard

According to this classification, the ground water in York County, which ranged from 136 to 279 ppm in hardness, is hard or very hard, as its users have probably discovered.

Silica concentrations in the ground water were high, ranging from 32 to 45 ppm. According to the California Institute of Technology (1957), high concentrations of silica can result in scale formation in boilers.

Most irrigators are interested in how the water used for irrigation will affect the soil and crops. The U.S. Salinity Laboratory Staff (1954) investigated the effects of different waters on soils and crops and found that the following four characteristics of water are of major importance: salinity hazard, sodium hazard, concentration of residual sodium carbonate, and concentration of boron.

The salinity hazard indicates the tendency of a water to cause salt accumulation in the soil (U.S. Salinity Laboratory Staff, 1954, p. 79). It depends on the amount of dissolved solids in the water (as measured by the specific conductance). The ground water in York County has a medium salinity hazard, which means that the water can be used satisfactorily to irrigate plants with moderate salt tolerance, provided that a moderate amount of leaching occurs. If uniform recharge of 1.5 inches is assumed to occur throughout York County, then some leaching must result from precipitation percolating through the soil. However, if an appreciable part of the recharge is from stream valleys and poorly drained depressions, only a small part of the natural recharge by precipitation may be effective as a leaching agent for the irrigated soils.

The sodium hazard indicates the tendency of a water to cause high levels of exchangeable sodium in a soil and thereby cause the soil to pack easily (U.S. Salinity Laboratory Staff, 1954, p. 81). It depends on the amount of sodium in the water in relation to the amounts of calcium, magnesium, and total dissolved solids, and is determined from the sodium-adsorption-ratio and the specific conductance of the water. The ground water in York County has a low sodium hazard, which means that it can be used on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees may accumulate injurious concentrations of sodium.

Residual sodium carbonate in excess of about 1.25 equivalents per million may cause a soil condition known as black alkali (Eaton, 1950). The residual sodium carbonate was less than 0.8 equivalents per million for all samples; therefore, development of black alkali from use of the water is unlikely.

The amount of boron in the water ranged from 0.03 to 0.14 ppm; and according to Scofield's boron classification (1936), the water is class 1 (excellent for all types of crops).

SELECTED REFERENCES

American Society for Testing Materials, 1960, Manual on industrial water and industrial waste water; Second edition with new and revised methods—1959: Spec. Tech. Pub. 148–D, 658 p.

Eaton, F. M., 1950, Significance of carbonates in irrigation waters: Soil Sci., v. 69, no. 2, p. 123–133.

California Institute of Technology, 1957, Water quality criteria: State Water Pollution Control Board Pub. 3, 676 p.

Hayes, F. A., and Goke, A. W., 1928, Soil Survey of York County, Nebraska: U.S. Dept. Agriculture, State Soil Survey Rept. 10, 37 p.

Keech, C. F., 1964, Basic-data report, York County, Nebraska: Nebraska Univ., Conserv. and Survey Div., Nebraska Water Survey Paper 16, 38 p.

Nordquist, A. V., and Logan, K. E., 1965, Nebraska agricultural statistics, annual report 1963, preliminary report 1964: State [Nebraska]-Federal Div., Agriculture Statistics, 144 p.

Rainwater, F. H., and Thatcher, L. L., 1960, Methods for collection and analysis of water samples: U.S. Geol. Survey Water-Supply Paper 1454, 301 p.

Scofield, C. S., 1936, The salinity of irrigation water: Smithsonian Inst. Ann. Rept., 1935, p. 275–287.

Smith, F. A., 1963, Logs of test holes in York County, Nebraska: Nebraska Univ., Conserv. and Survey Div., Nebraska Water Survey Test Hole Rept. 5, 60 p.

U.S. Public Health Service, 1961, Drinking water standards: Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935–945.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agriculture, Agriculture Handb. 60, 160 p.